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Effects of Water Stress and Pod Position on the Seed Quality of Chickpea (*Cicer arietinum* L.) Cultivars

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Abstact

A field experiment was carried out in 2008 to evaluate the effects of different irrigation treatments (I_1, I_2 and I_3: irrigation after 70, 120 and 170 mm evaporation from class A pan, respectively) and pod positions (upper, lower and middle parts of the canopy) on the seed quality of four chickpea cultivars ('Jam', 'Hashem', 'Arman' and 'ILC' from Kabuli type). Seed quality as determined by means of the electrical conductivity of seed leachates, germination percentage, germination rate and seedling dry weight were not significantly affected by water stress, but mean seed weight decreased with increasing irrigation intervals. The largest seeds with the highest quality were obtained from the lower parts of the canopy. No significant interaction of irrigation *versus* seed position indicated that seeds of lower position had high quality under both adequate and limited irrigations. 'ILC' had larger and more vigorous seeds compared to other cultivars. Mean seed weight, germination percentage, germination rate and seedling dry weight had positive and significant correlation with each other. It was concluded that sorting chickpea seeds for large and uniform size after harvest could be a practical way of improving seed lot quality.

Keywords: chickpea, limited irrigation, pod position, seed quality

Introduction

Chickpea (*Cicer arietinum* L.) is one of the major pulse crops throughout the world. Most of the chickpea growing areas in Iran have cool and cold semiarid climates with terminal drought stress. In NW Iran, chickpea is sown from mid-March to the end of April and grows mainly on reserve moisture which is progressively depleted with crop growth. The crop experiences drought stress from the late vegetative stages until maturity. The intensity of drought stress varies from year to year, depending on temperature variation and the amount and distribution of rainfall (Soltani *et al*., 2001). Chickpea cultivars used in Iran have been subjected to little breeding work, and consequently chickpea yield is limited by climatic factors, water availability and genotype.

Germination and seedling establishment are critical stages in the plant life cycle. In crop production stand establishment determines plant density, uniformity and management options (Cheng and Bradford, 1999). In arid and semi-arid environments, the water needed for germination is available for only a short period, and consequently, successful crop establishment depends not only on the rapid and uniform germination of the seed, but also on the ability of the seed to germinate under low water availability conditions (Fischer and Turner, 1978). However, if the stress effect can be alleviated at the germination stage, chances for attaining a good crop with economic yield production would be high (Ashraf and Rauf, 2001). While the time of sowing can influence crop establishment, it also dictates the environment experienced during seed development, both within and above the crop canopy (Castillo *et al*., 1994).

High quality seed lots may improve crop yield in two ways: first because seedling emergence from the seedbed is rapid and uniform, leading to the production of vigorous plants and second because percentage seedling emergence is high, so optimum plant population density could be achieved under a wide range of environmental conditions (Ghassemi-Golezani, 1992). These are the main reasons for farmers, who are interested to buy and cultivate vigorous seeds. Thus, production of high quality seeds is an important strategy for seed producers. Factors other than environment can also alter seed size and quality. In non stressed soybean plants, seeds located within the upper canopy had a higher germination percentage and a greater seedling growth rate than seeds from the lower canopy (McDonald *et al*., 1983). For an indeterminate soybean cultivar, Keigley and Mullen (1986) found that seeds from the middle stem region exhibited greater seedling weight compared to seeds from other regions of the stem. Pod position can also influence the response of weight per seed to the application of supplemental water. Wallace (1986) reported that irrigation increased weight per seed and pod number in the lower canopy branches compared with similar branches on non-irrigated plants. Thus, pod position during a drought stress may be an important factor in the determination of seed physiological quality. This research was undertaken to examine the effects of pod position and water stress on chickpea seed germination and vigor.

Materials and methods

A split-split plot experiment (using RCB design) with 3 replications was conducted in 2008 at the Research Farm of the Faculty of Agriculture, University of Tabriz, Iran (latitude 38.05°, longitude 46.17°E, altitude 1360 m). The climate is characterized by mean annual precipitation of 245.75 mm per year, mean annual temperature of 10°C, annual maximum temperature of 16.6°C and mean annual minimum temperature of 4.2°C.

Irrigation regimes (I_1, I_2 and I_3: irrigation after 70, 120 and 170 mm evaporation from class A pan, respectively) were located in main plots and cultivars ('Jam', 'Hashem', 'Arman' and 'ILC' from Kabuli type) were allocated to sub plots. Pod positions were considered as sub-sub plots. Seeds of chickpea cultivars were treated with 2 $g.kg^{-1}$ Mancozeb and then were sown by hand on 24 May 2008 in 5 cm depth sandy loam soil. At the same time, plots were fertilized with 100 $kg.ha^{-1}$ Ammonium Phosphate. Each plot consisted of 6 rows of 4 m length, spaced 25 cm apart. All plots were irrigated immediately after sowing, but subsequent irrigations were carried out according to the treatments. Hand weeding of the experimental area was performed as required.

At the maturity stage, when seed moisture content was 16-18%, seeds of the plants at 2 m^2 of each plot were separately detached from the upper, middle and lower parts of the canopies. Seed moisture content was determined in accordance with ISTA rules (1985). Subsequently, seeds were ambient air dried and 1000 seed weight of each sample was determined. Seed samples within separate sealed bags were then placed in a refrigerator at 3-5°C.

Seed quality tests were carried out at the Seed Technology Laboratory of Tabriz University. Four replicates of 25 seeds from each sample were treated with 2.5 $g.l^{-1}$ Thiram for about 1 min, before testing. Seeds of each replicate were placed between two 30 x 30 cm wetted and rolled filter papers, which were then placed in plastic bags to prevent water loss. These bags were incubated at 10±1°C for 10 days. Germinated seeds (protrusion of radicle by 2 mm) were counted in daily intervals. At the end of each test, normal and abnormal seedlings were recorded (ISTA, 2005) and the germination percentage was calculated. Rate of seed germination was calculated according to Ellis and Roberts (1980).

Where n is the number of seeds germinated on day D, D is the number of days counted from the beginning of the test and Ŕ is the mean germination rate. Seedlings were then dried in an oven at 80°C for 24 hours (Perry, 1977) and mean seedling dry weight for each treatment at each replicate was determined.

Two replicates of 50 seeds from each sample were weighed (SW_1 and SW_2) and then seeds of each replicate immersed in 250 ml deionized water in a container at 20°C for 24 hours. The seed-steep water was then gently decanted and electrical conductivity (EC) was measured, using an EC meter (EC_1 and EC_2). The following equation was applied to calculate conductivity per gram of seed weight for each sample (Powell *et al*., 1984):

$$EC\ (\mu s/cm/g) = [(EC_1/SW_1) + (EC_2/SW_2)]/2$$

All the data were analyzed on the basis of experimental design, using MSTATC and SPSS software. The means of each trait were compared according to Duncan test at P≤0.05. Excel software was used to draw figures.

Results and discussion

Analysis of variance of the data showed significant effects of cultivar and pod position on 1000 seed weight, germination rate, germination percentage and seedling dry weight. Electrical conductivity of seed leachates was not significantly affected by cultivar, pod position and irrigation treatments. The effect of irrigation was only significant for 1000 seed weight. Cultivars × pod position interaction was also significant for 1000 seed weight (Tab. 1).

Tab. 1. Analysis of variance of the effects of water limitation and pod position on seed quality parameters of chickpea cultivars

Source	Degrees of freedom	1000 seed weight	Electrical conductivity	Germination percentage	Germination rate	Seedling dry weight
Replication	2	390.48ns	1.086 ns	1.23ns	0.93ns	1003.70 ns
Irrigation(I)	2	45461.34**	0.594 ns	6.79ns	9.51ns	3837.04 ns
Error	4	1742.87	0.299	4.55	5.51	3392.59
Cultivar (C)	3	27553.90**	0.209 ns	90.36**	244.06**	83095.06**
I*C	6	1596.73ns	0.147 ns	6.47ns	8.39ns	4424.69 ns
Error	18	652.69	0.135	4.27	4.17	2951.85
Position (P)	2	5319.68**	0.098 ns	55.26**	52.48**	9603.70**
I*P	4	318.40 ns	0.064 ns	1.12ns	2.73ns	2059.26 ns
C*P	6	937.39 **	0.167 ns	1.35ns	1.84ns	1198.77ns
I*C*P	12	333.41 ns	0.137 ns	1.15ns	1.10ns	1283.95 ns
Error	48	311.273	0.130	1.58	1.87	1246.30
CV %		5.76	1.6	1.31	4.73	7.14

*,** Significant at P≤0.05 and P≤0.01, respectively

Tab. 2. Mean seed quality parameters of chickpea affected by pod position

Pod position	1000 seed weight (g)	Germination percentage	Germination rate (per day)	Seedling dry weight (mg)
Up	0.280±8.06[b]	94.75±0.36[b]	0.280±0.52[b]	481.1±10.57[b]
Middle	0.284±7.14[b]	95.19±0.35[b]	0.284±0.52[b]	490.0±10.31[b]
Low	0.303±8.08[a]	97.08±0.43[a]	0.303±0.52[a]	512.8±11.55[a]

Different letters at each column indicating significant differences at P≤0.05

Tab. 3. Mean seed quality parameters for chickpea cultivars

Cultivars	1000 seed weight (g)	Germination percentage	Germination rate (per day)	Seedling dry weight (mg)
'Jam'	308.9±4.66[b]	95.78±0.24[a]	0.289±0.23[b]	497.8±4.69[b]
'Hashem'	309.4±6.73[b]	96.67±0.39[a]	0.296±0.39[b]	503.0±10.66[b]
'Arman'	264.9±9.73[c]	93.07±0.38[b]	0.249±0.46[c]	421.5±9.89[c]
'ILC408'	342.8±7.81[a]	97.19±0.39[a]	0.322±0.40[a]	556.3±8.34[a]

Different letters at each column indicating significant differences at P≤0.05

Mean 1000 seed weight significantly decreased as the the severity of water stress increased (Fig. 1). The highest 1000 seed weight, germination rate, germination percentage and seedling dry weight were obtained for seeds of lower position, but no significant differences in quality parameters of upper and middle seeds were observed (Tab. 2).

'ILC' was a superior cultivar in mean 1000 seed weight, germination rate and seedling dry weight. These traits in 'Jam' and 'Hashem' cultivars were statistically similar. The lowest seed quality parameters were observed in 'Arman' (Tab. 3). No significant differences in 1000 seed weight of 'Jam' and 'Hashem' at different plant positions were observed. However, in 'Arman' and 'ILC', mean 1000 seed weight of lower plant position was significantly higher than that of middle and upper positions (Fig. 2).

The 1000 seed weight was positively and significantly (p≤0.01) correlated with germination rate, germination percentage and seedling dry weight. However, electrical conductivity of seed-steep water negatively and not significantly correlated with other parameters. Germination percentage, germination rate and seedling dry weight had also significant and positive correlation with each other (Tab. 4).

Reduction in mean seed weight of chickpea with increasing water limitation (Fig. 1), could result from the stimulation of seed maturity under stress as reported in lentil (Erskine and Ashkar, 1993), chickpea (Silim and Saxena, 1993), wheat (Li *et al*., 2000), barley (Samarah, 2005) and common bean (Gassemi-Golezani and Mazloomi-Oskooyi, 2008). Seed quality as measured by electrical conductivity of seed leachates, germination percentage, germination rate and seedling dry weight was not significantly affected by water stress (Tab. 1). Similarly, Ghassemi-Golezani *et al*. (1997) reported that water stress has no significant effect on seed quality of maize and sorghum, but it can considerably reduce seed yield. This is also supported by previous reports on soybean (Vieira *et al*., 1992) and common bean (Ghassemi-Golezani and

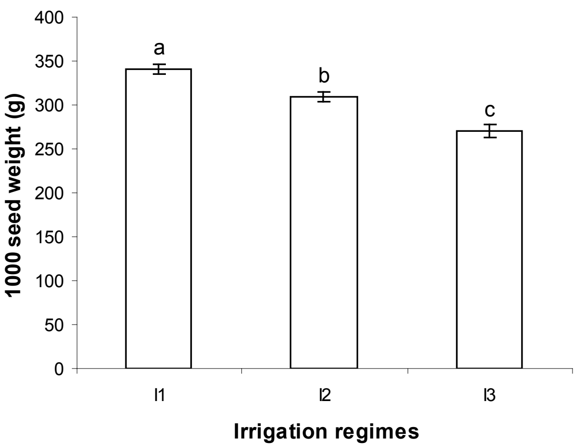

Fig. 1. Mean 1000 seed weight under different irrigation regimes I1, I2 and I3: irrigation after 70, 120 and 170 mm evaporation from class A pan, respectively

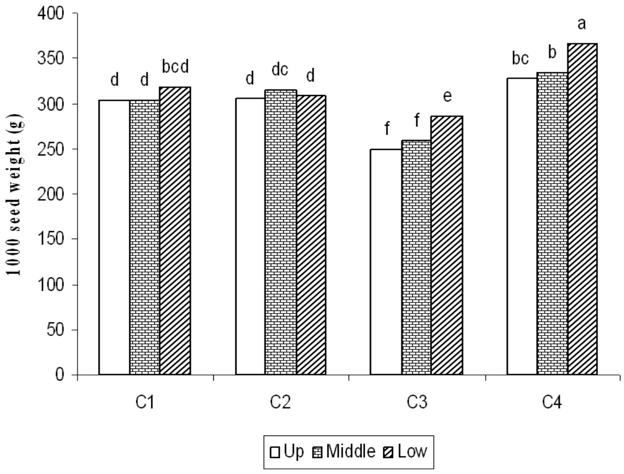

Fig. 2. Mean 1000 seed weight of chickpea cultivars affected by pod position C1, C2, C3 and C4: 'Jam', 'Hashem', 'Arman' and 'ILC', respectively

Tab. 4. Correlation coefficients of various seed quality parameters in chickpea

Trait	1000 seed weight	Electrical conductivity	Germination percentage	Germination rate	Seedling dry weight
1000 seed weight	1				
Electrical conductivity	- 0.279	1			
Germination percentage	0.770**	- 0.042	1		
Germination rate	0.815**	- 0.007	0.943**	1	
Seedling dry weight	0.829**	- 0.028	0.868**	0.970**	1

** Significant at P≤0.01

Mazloomi-Oskooyi, 2008). This demonstration that irrigation can not substantially affect seed quality is only of practical interest to commercial seed producers, but is not of relevance to the elucidation of those factors responsible for seed quality.

Seeds of lower parts of the canopies exhibited higher quality, compared with those of middle and upper plant positions. This could be attributed to early formation and longer duration of pod filling at lower parts of the chickpea plants which resulted in the production of larger seeds (Tab. 2). In contrast, Dornbos and Mullen (1985) reported that larger and better quality seeds were obtained from the upper half of the main stem of soybean in comparison with seeds from the rest of the plant, when drought stress occurred during the seed-filling phase. A positive relation between seed size and quality in soybean was also reported by Dornbos *et al*. (1989). No significant interaction of irrigation × seed position (Tab. 1) suggest that seeds of lower position had high quality under both full and limited irrigation conditions. Thus, sorting chickpea seeds for large and uniform size after harvest could be a practical way of improving seed lot quality.

'ILC' produced larger and more vigorous seeds as indicated by higher germination rate and seedling dry weight, compared with other cultivars (Tab. 3). The superiority of 'ILC' in seed size was more evident at the lower part of crop canopy (Fig. 2). Seed size is considered to be a significant factor only during the early stages of growth (Ghassemi-Golezani, 1992). Singh *et al*. (1972) reported that large seeds of soybean had a greater supply of stored energy to support early seedling growth. Therefore, production of large seedlings by 'ILC' could be the result of having large seeds and high rate of seed germination (Tab. 3).

A significant positive correlation of 1000 seed weight with seedling dry weight (Tab. 4) suggests that the heavier seeds can produce larger seedlings. The advantage of large seeds in enhancing the seedling size lies in their higher reserve content and the ability to provide energy to the growing seedling at a faster rate (Ghassemi-Golezani, 1992). Significant correlations of germination rate and percentage and seedling dry weight with each other means that the germination test can provide sufficient information about the quality of chickpea seeds. This can considerably reduce the time and the cost of seed quality testing.

Conclusions

Water stress has no significant effect on seed quality of chickpea cultivars, but it can significantly reduce seed size. Seeds of lower position have a high quality under both full and limited irrigation conditions. Therefore, sorting chickpea seeds for a large and uniform size after harvest could improve seed lot quality.

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